(12) UK Patent Application (19) GB (11) 2 291 753 (13) A

(43) Date of A Publication 31.01.1996

(21) Application No 9514944.9

(22) Date of Filing 17.07.1995

(30) Priority Data
(31) 9414439 (32) 16.07.1994 (33) GB

(71) Applicant(s)
Peter Fred Blomley
2 Oakleigh Court, Maple Avenue,
BISHOPS STORTFORD, Hertfordshire, CM23 2RT,
United Kingdom

(72) Inventor(s)
Peter Fred Blomley

(74) Agent and/or Address for Service
Keith W Nash & Co
Pearl Assurance House, 90-92 Regent Street,
CAMBRIDGE, CB2 1DP, United Kingdom

(51) INT CL^6
H03D 7/00 // H03D 7/12 7/14

(52) UK CL (Edition O)
H3R RMX

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition N) H3R RMB RMC RMX
INT CL^6 H03B , H03D
Online: WPI, JAPIO

(54) **Signal mixer**

(57) A class AB mixer combines a signal i.e. a square wave, from a local oscillator (26) with two unidirectional pulse trains (23, 25) which, in combination, represent an input signal in phase and amplitude. Input circuitry (20) generates the pulse trains by splitting alternate half wave cycles of the input signal into two components and inverting the polarity of one of said components. The pulse trains have the same polarity and revert substantially to zero voltage and current between pulses, thereby to reduce switching noise in the mixer. The RF input signal may be applied via an RF amplifier 21 and a driver 20 which may be of the class AB or B type. The input signal may alternatively be applied via a transformer to respective bases of two drive transistors. The bases of the mixer transistors Q2, Q3 may be connected to a common bias voltage or respectively connected to bases of Q4, Q1.

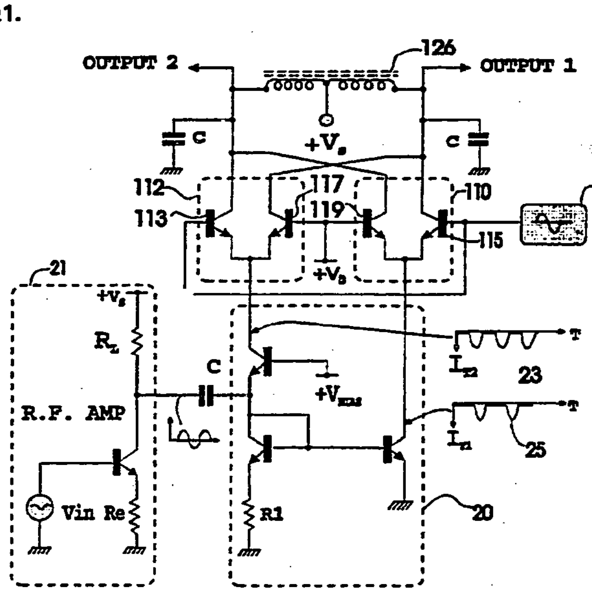
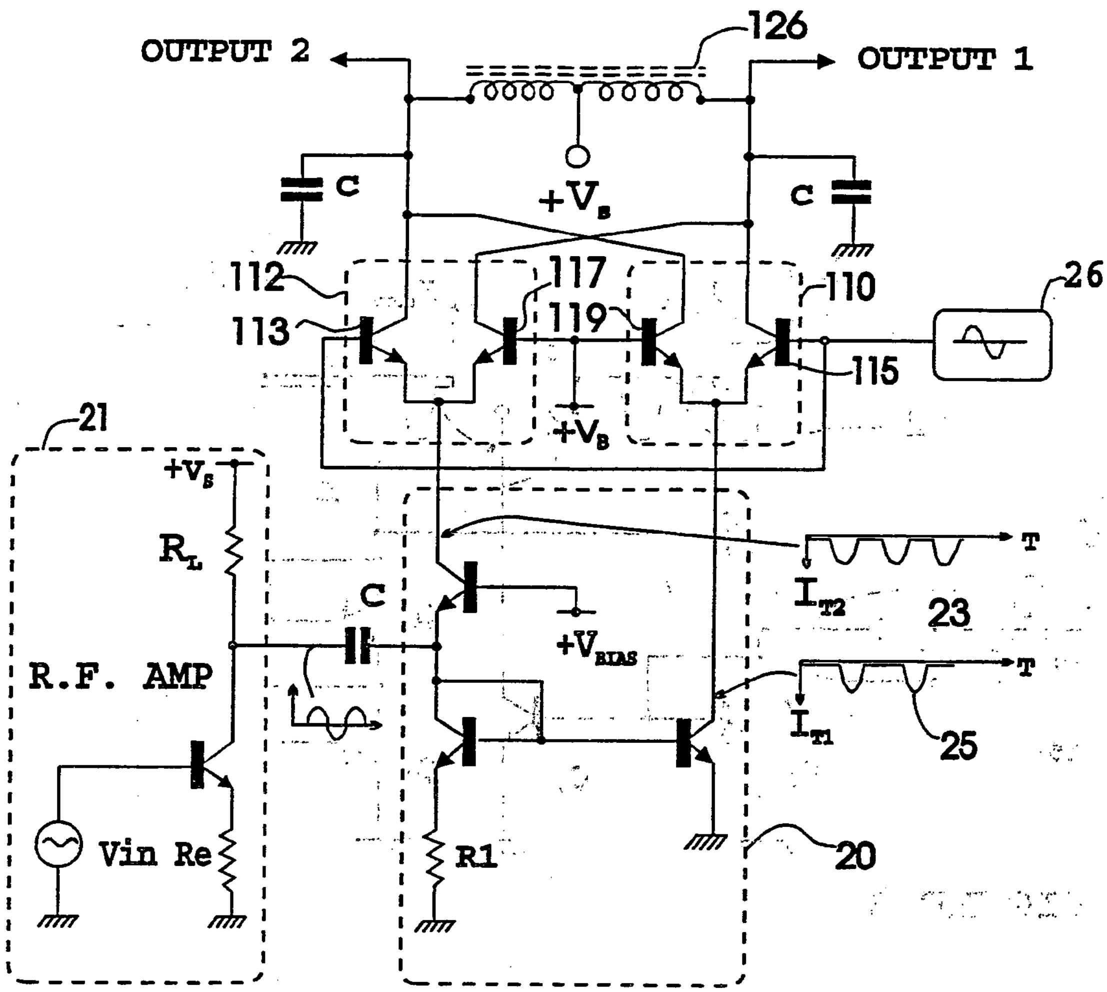


FIGURE 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirem nts of the Patents Rules 1995

GB 2 291 753 A



OUTPUT 2
126
OUTPUT 1
C
+V_S
C
112
117
110
26
113
119
115
21
+V_B
+V_S
R_L
C
I_T2
T
23
+V_BIAS
R.F. AMP
T
I_T1
25
Vin Re
R1
20

FIGURE 1

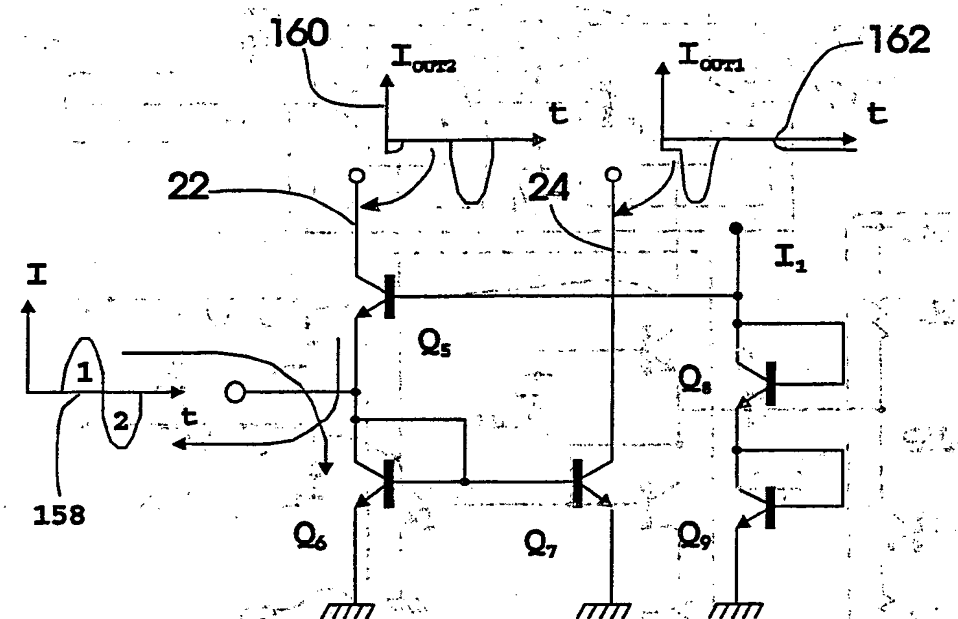


FIGURE 2

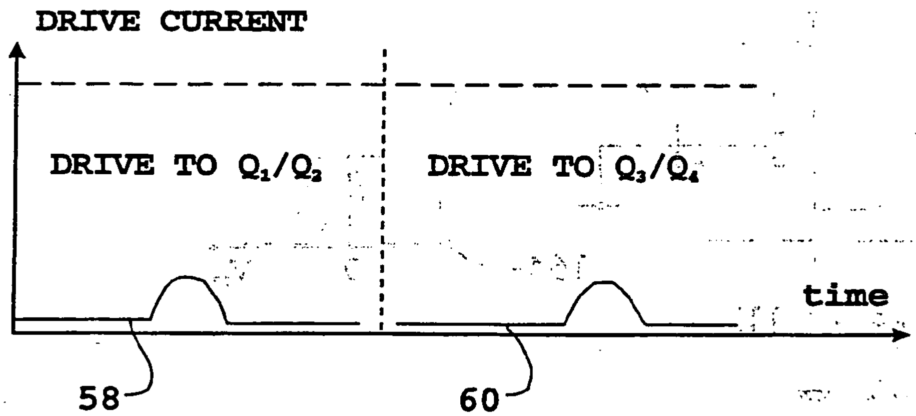


FIGURE 3(a).

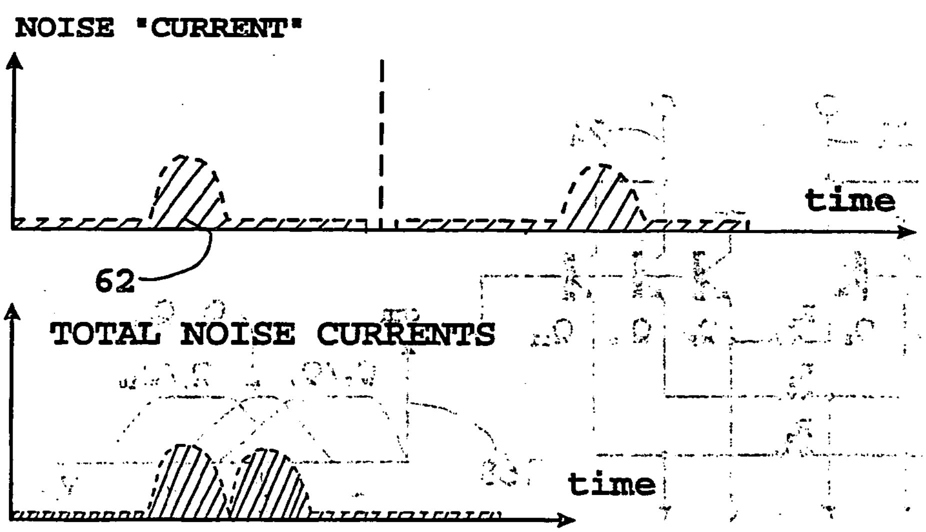


FIGURE 3(b).

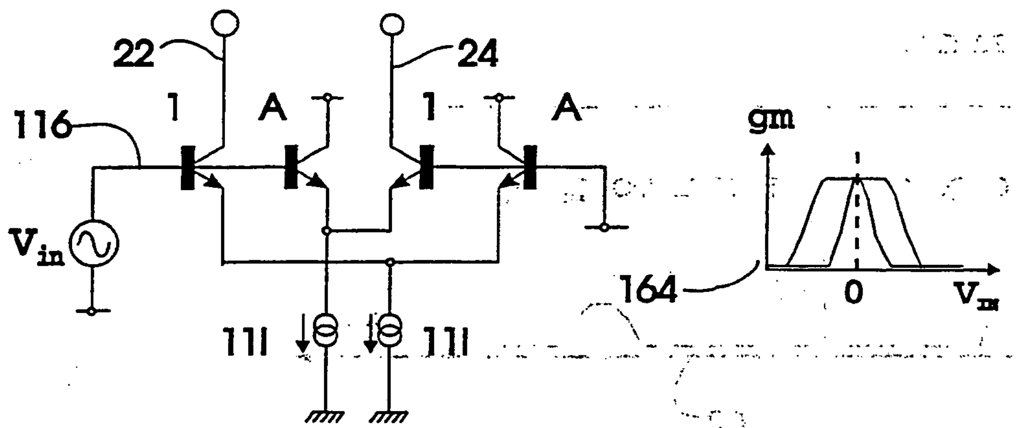


FIGURE 4

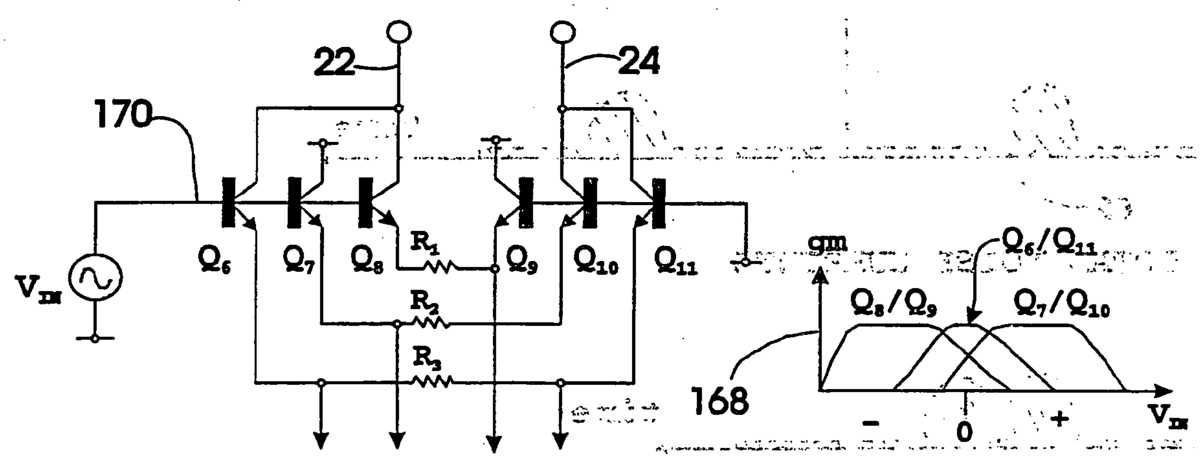


FIGURE 5

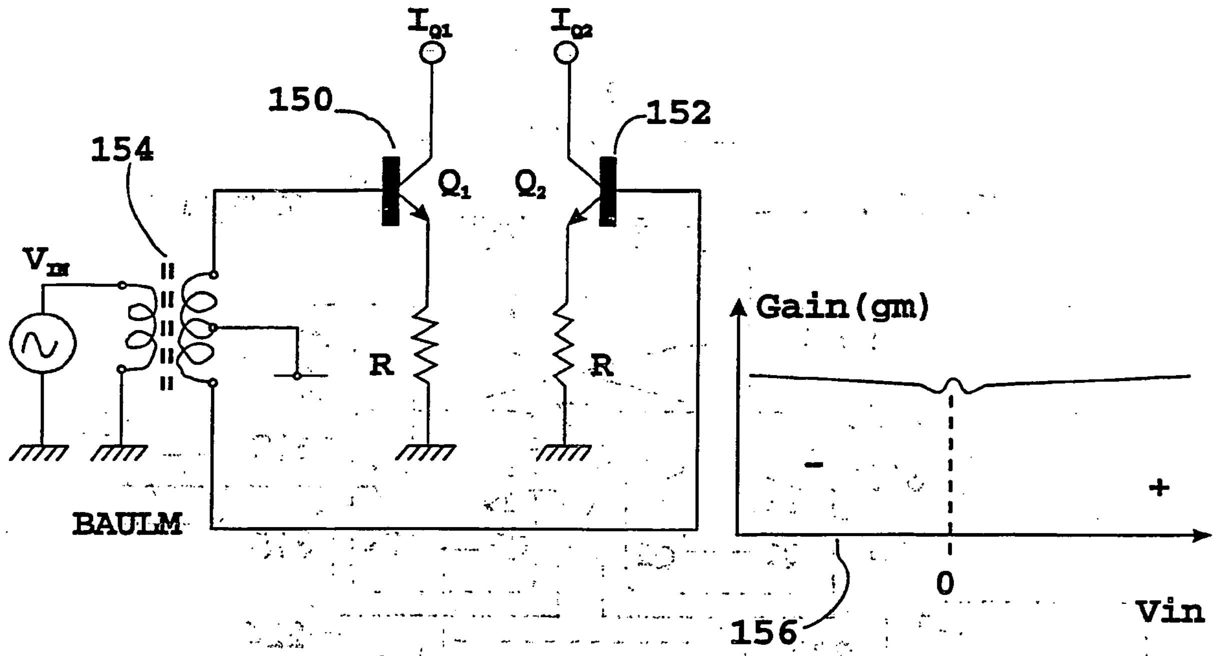


FIGURE 6.

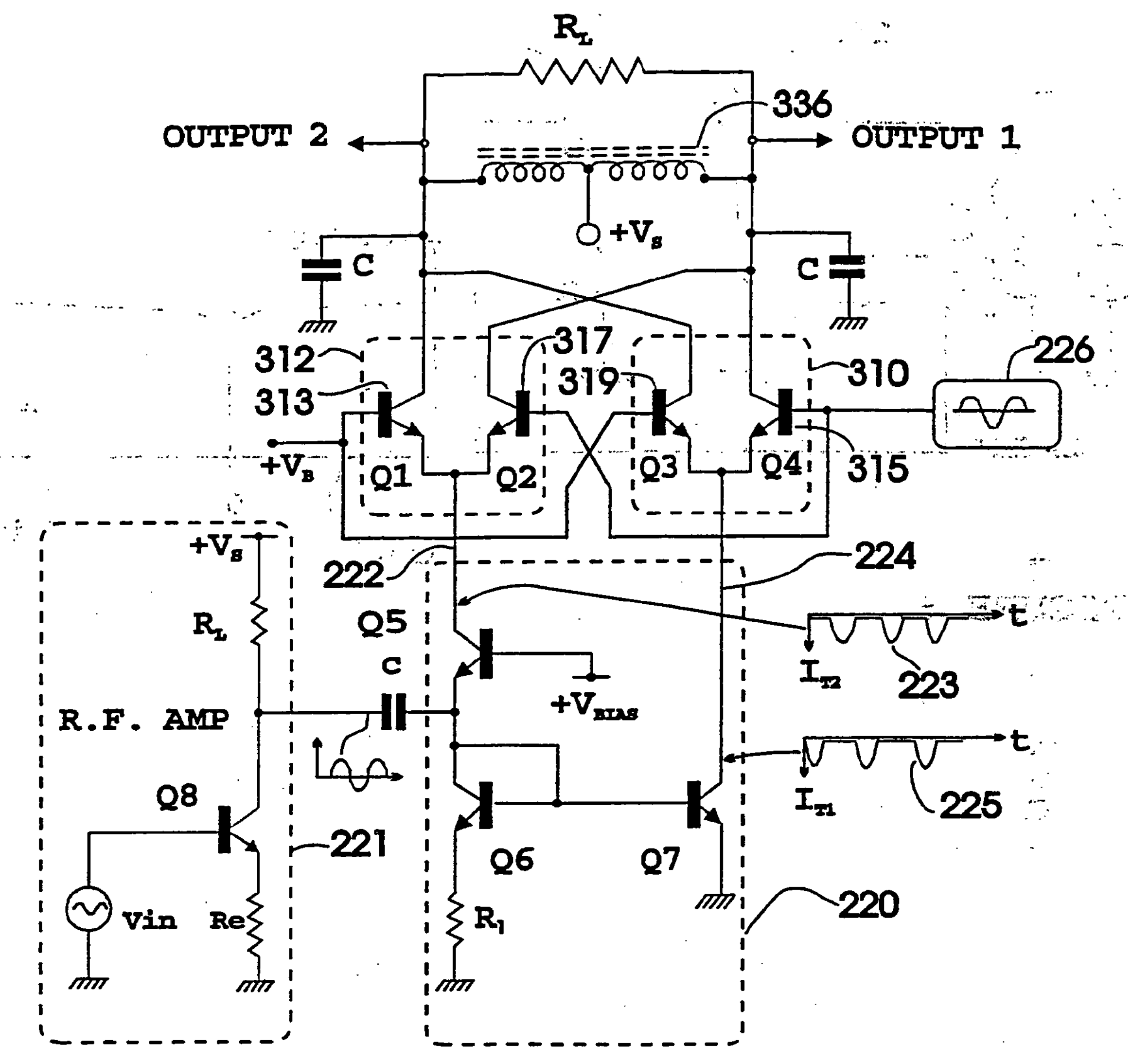

R_L
OUTPUT 2
OUTPUT 1
336
+V_s
C
C
312
313
317
319
310
226
315
+V_B
Q1
Q2
Q3
Q4
+V_s
R_L
R.F. AMP
222
224
Q5
C
+V_BIAS
t
I_T2
223
t
I_T1
225
Q8
221
Q6
Q7
220
Vin
Re
R_1

FIGURE 7

C471/B

Title: Signal Mixer

Field of the invention

This invention relates to mixers, and more particularly to a mixer for use in radio frequency (R.F.) signal processing circuitry, and to a driver for use in such a mixer.

Background to the invention

Signal mixers are commonly used to translate (ie shift) the frequency of the carrier of an R.F signal to an intermediate frequency, which is independent of the frequency of the carrier to facilitate further processing by frequency sensitive circuitry.

This is achieved by mixing the input signal with a constant frequency alternating control signal for a local oscillator so as to produce a composite signal of a number of frequencies. The composite signal is filtered so as to leave as an output signal only the component having the desired frequency (usually the difference signal).

One example of a known type of mixer is a monolithic Gilbert Mixer (B Gilbert Four Quadrant Multipliers Solid State Circuits Vol SC-3 No 4 pp 365-373).

Summary of the invention

According to the present invention, a mixing means has three inputs, one for the local oscillator signal, and two others for unidirectional pulse trains derived from the input signal, to produce, inter alia, sum and difference signals, wherein the

unidirectional pulse trains are obtained by selecting alternate half cycles of the input signal and inverting the polarity of one of the selected pulse trains so both have the same polarity and both signals revert substantially to zero current and zero voltage between pulses.

Since the excursions of the pulse trains are all either positive going or negative going, the invention avoids the need for a relatively large dc component to be included in the quiescent signal. This has been found to improve the noise performance of the mixer, and to offer a significant extension of dynamic range compared with a conventional mixer.

Preferably, the mixing means includes amplifying means for increasing the magnitude of the pulse trains relative to the input signal prior to the mixing of the driver signal.

To that end, the mixing means may to advantage include an interconnected cascade of transistors.

Brief description of the drawings

Various embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a circuit diagram of a mixer having mixing means according to the present invention and shows some sketch graphs of currents passing through various parts of the circuit;

Figure 2 is a diagram of alternative circuitry for part of the mixer shown in Figure 1 and also includes sketch graphs of input and output currents for the circuitry;

Figure 3a is a sketch graph of one pulse in each of the pulse trains fed to two of the inputs of the mixing means;

Figure 3b shows two sketch graphs illustrating the noise produced by the mixing means;

Figures 4, to 5, show alternative circuitry to that shown in Figure 2 and each includes a sketch graph of the gain against input voltage for the respective circuitry; and

Figure 7 shows an alternative mixer, in accordance with the invention.

Detailed Description

The mixer shown in Figure 1 is a current switching mixer which effectively multiplies a square wave control signal produced by a local oscillator 26 with two pulse trains which are derived from an input R.F. signal, respectively fed to the inputs 22 and 24.

The mixer comprises two pairs of emitter coupled switching transistors 110 and 112. The output from the oscillator 26 is connected directly to the base of one member, respectively referenced 113 and 115, of each pair. The base of the other member, 117 and 119, of each pair is connected to the oscillator 26 through circuitry which inverts the control signal so that the signal fed to the bases of the transistors 117 and 119 is of opposite polarity to the signal fed to the bases of transistors 113 and 115.

The transistors 113 and 115 conduct currents from the inputs 22 and 24 when the signal from the oscillator 26 is positive. When the polarity of the oscillator signal changes, the transistors 117 and 119 conduct the currents from input 22 and 24.

The collector currents for the pairs of transistors are fed through a transformer 126, which provides a balanced output mixer load for combining the outputs of the pairs of transistors. As an alternative to the transformer 26, the collectors of the

transistors could be connected to a current mirror (not shown).

The inputs 22 and 24 are connected to input circuitry 20 which acts as a class AB driver and which is in turn connected to an R.F. voltage amplifier 21 for relaying the input signal to the driver 20. The driver 20 splits the signal from the amplifier 21 into two components, each containing respective half wave cycles of the input. One of those components, indicated by I_{T1}, is then inverted so that the driver 20 produces two trains of negative polarity current pulses (eg 23 and 25) from a quiescent level as indicated by Iq. These pulses drive the transistors 113, 115, 117 and 119.

The difference between the current in each pulse and zero current is always greater than the difference between the quiescent current and zero current. Thus the direction of the current constituting the pulse trains remains unchanged, regardless of the amplitude of the signal, even if Iq is very close to zero.

The graphs 58 and 60 in Figure 3a illustrate current against time for two individual excursions in the driver signal, which, together, correspond to a single wave cycle of the input signal.

It can be seen that only a low quiescent current is needed to ensure that the transistors Q1-Q4 remain forward biased. This results in low switching noise levels (partition and thermal noise) being produced by the transistors Q1-Q4 as is indicated by the graph 62 in Figure 3b.

Figure 2 shows input circuitry which corresponds to the driver 20, but which is adapted to receive signals from an R.F. current amplifier, rather than the R.F voltage amplifier 21. The pulse trains produced by the driver shown in Figure 2 correspond to those produced by the driver 20. The inputs for receiving the signals produced by the circuitry shown in Figure 2 are also denoted by the reference numbers 22 and 24. Sketch graph 158 is of one cycle of the signal from the current amplifier, and sketch

graphs 160 and 162 show the resultant pulses fed to the transistor pairs 110 and 112.

Figure 4 shows an alternative form of input circuitry, which employs a cascade of transistors which increases the gain in the driver output. The sketch graph 164 shows that the gain of this circuit is substantially uniform over a range of input voltages (at input 166), but falls away at extreme magnitudes of input voltage.

As an extension of this principle, the driver circuitry shown in Figure 5 acts as a large voltage class AB input circuit, and includes a larger number of transistors connected in the form of a cascade, in order to increase the amount of gain in the driver output. As can be seen from sketch graph 168, the range of input voltages (at input 170) over which the gain is uniform is larger than that for the circuitry shown in Figure 4.

In both Figures 4 and 5, reference numbers 22 and 24 denote the driver outputs which correspond to the outputs 22 and 24 of the driver 20.

Figure 6 shows a balanced class AB input circuit which can be used as a driver for the mixer. An input signal is fed to the bases of a pair of transistors 150 and 152 via a transformer or Balum (Balanced to unbalanced transformer) 154. As can be seen from graph 156, the gain of this circuit is substantially flat, apart from when the input voltage is in the region of zero volts.

A further discussion of the present invention and the prior art follows.

A mixer in accordance with the present invention enables both low noise levels and low total power consumption of the input R.F. module to be achieved.

The mixer, which will be referred to as a Class AB mixer is shown

in Figure 1. The driver 20 uses a Class B approach to the drive of the mixer pairs 110 and 112 to reduce the excess noise created by the switching transistors (Q1-Q4) used in the mixing process. At the same time this Class B approach is also designed to keep the mixers forward "transfer gain" and the output drive capability constant. It can be shown that the excess current noise of the mixer pairs (Q1-Q4) is almost directly proportional to the tail current (I_T) apart from additional contributions, from the terminal noise of the base resistance of the these transistors, which only occurs at high tail currents.

The mixer shown in Figure 1 makes use of a Class AB current driver (driver 20 or the current driver shown in Figure 2). This is a current steering design which is extremely fast and defines two half wave forms the total of which constitutes the input signal current wave form. The outputs of this "signal splitter" circuit are the two collector currents of device Q5 and Q7. These unidirectional currents drive each switching pairs, with a wave form shown in Figure 3(a) at 58 and 60. The function of this circuit is to rectify the AC current output from Q8 and split the top and bottom half of the drive currents. These two unidirectional signal currents (I_{T1} & I_{T2}) are now fed into each half (+ or - currents) of the relevant mixing pairs (Q1-2 & Q3-4). A fully balanced output mixer load is added (a transformer or a current mirror Q9 & Q10) which now adds the two mixed half outputs from the switching pair (A & B) to reconstruct the total output frequency shifted output wave form.

By using this Class AB mixer design the switching current in the mixer pairs is now directly dependent on the input signal, in direct contrast to the constant quiescent conditions used in a Class A mixer. At small R.F. levels the Class AB mixer will only produce noise at the peaks of the signal (depending on the quiescent conditions). Typical noise outputs from a Class AB mixer is shown in Figure 3 (b) top graph. It follows therefore that, as the current in the switching mixer pairs creates most of the excess noise, this approach should achieve very good noise

performanc in most conditions. Equally, the output current capability (at A & B) of th mixer is also directly proportional to the instantaneous current at the two input tails (C & D) of the mixer pairs.

Hence the output current of this approach would be equal to the normal Class A designs using the same total current as the input driver (Q8). However the significant improvement of the noise performance of the Class A of Figure 1 mixer, coupled with this same output current drive which offers a significant extension to the dynamic range, over the normal Class A mixer approach.

Furthermore the input R.F. amplifier 21 (Q8 etc) can now form part of the total mixer circuit thus the total power consumption of the R.F module is now lower. The mixer pairs will only take a significant current from the supply when the input R.F. level is high. Compared with a normal Class A design this system will only consume about half the quiescent power of a comparable input R.F./Mixer module.

A mixer embodying the present invention normally has three inputs, one for the local oscillator (LO) drive (typically of constant amplitude) and the other two are the input (which has to handle extremely large range of signal amplitudes) and the mixer output which can be single or double balanced. In order to improve the performance of the present monolithic Gilbert Mixers (ref B Gilbert Four Multipliers Solid - State Circuits Vol SC-3 No 4 pp 365-373) this invention splits the mixer function into two main blocks (circuits). The total functionality of the mixer remains the same but the approach to the internal design of the mixer is different.

The first circuit (A) shown in Figure 2 interfaces with the input signal source, rectifies these input signals and then creates two unidirectional currents the total of which represent the original input signal in both amplitude and phase. These two unidirectional currents (Iout1 and Iout2) now feed into the

second circuit (B) of the mixer (top half of fig 1) which comprises of two identical unidirectional mixer elements 112 & 110 and an output summing circuit (transformer 126).

Both of these mixer elements in 110 & 112 are fed with the L.O. constant input level 26 drive at one terminal (normally the bases Q1 & Q4) and the unidirectional currents (Iout1 23 & Iout2 24) at the other terminal (the emitters C & D). The output from these two mixers circuits is again a unidirectional current whose output magnitude represents the mixing products of only one half wave form (either positive or negative) and the L.O. drive signal.

In order to recompose the final output of the mixer to a normal bi-directional output signal it is required to feed the mixing products from the outputs of these mixer elements into a standard difference circuit (such as a simple transformer 126 or a current mirror). The output of this difference circuit gives the required bi-directional mixer output but with this invention this output has the added advantage of lower noise and wider dynamic range.

There are several ways to produce these unidirectional "signal splitting" circuits, one of the simplest is the one shown in Fig 2. However, there are alternatives for this input circuit (A) such as shown in Figure 4 & Figures 5 and 6. This new combination can be shown to achieve a similar result but it is clear that the main advantage of the simple input circuit shown in Fig 2 is the total power consumed by the total mixer element is extremely low (input signal dependent) in most conditions.

The mixer circuit shown in Figure 7 has many components which correspond to those of the circuit shown in Figure 1 and are therefore denoted by the same reference numbers raised by 200.

Thus, the mixer shown in Figure 7 comprises four transistors 313, 315, 317 and 319 connected together as emitter coupled

switching pairs 310 and 312. The tails of the pairs 310 and 312 are connected to input circuitry 220 which acts as a class AB current driver, and which includes a pair of base coupled transistors Q6 and Q7, the collector currents of which take the form of unidirectional pulse trains 223 and 225 sunk from the emitters of the pairs 310 and 312.

The circuitry 220 is connected to input amplifier circuitry generally referenced 221 in which an input voltage (v_{IN}) is fed to the base of a transistor (Q5) the collector of which is connected to the circuitry 220 through a capacitor C.

The bases of the switching transistors 313, 315, 317 and 319 (Q1, Q2, Q3 and Q4) are connected in a way which differs from that of the corresponding transistors as shown in Figure 1. The bases of the transistors 317 and 319 are respectively connected to the bases of the transistors 315 and 313. The bases of the transistors 315 and 317 are connected directly to the internal oscillator 226, whilst the bases of transistors 313 and 319 are connected to the oscillator through inverting circuitry. Thus, the transistors 315 and 317 conduct currents from the inputs 222 and 224 when the signal from the oscillator 226 is positive. When the polarity of the oscillator signal changes, the currents from the inputs 222 and 224 are conducted by the transistors 313 and 319.

CLAIMS

1. Mixing means having three inputs, one for the local oscillator signal, and two others for unidirectional pulse trains derived from an input signal by input circuitry, to produce, inter alia, sum and difference signals, wherein the input circuitry is operable to obtain the unidirectional pulse trains by selecting alternate half cycles of the input signal and inverting the polarity of one of the selected pulse trains so both have the same polarity and both signals revert substantially to zero current and zero voltage between pulses.

2. Mixing means according to claim 1 in which the input circuitry is operable to increase the magnitude of the pulse trains relative to that of input signal prior to the mixing.

3. Mixing means according to claim 2 in which the input circuitry comprises an interconnected cascade of transistors.

4. Mixing means according to any of the preceding claims in which the mixing means comprises two emitter coupled pairs of transistors, the emitters of each pair constituting a respective input for the unidirectional pulse trains, and the bases of the pairs being connected to the input for the local oscillator.

5. Mixing means according to claim 4 in which a respective member of each pair is connected to the local oscillator input via circuitry for inverting the polarity of said local oscillator signal.

6. Mixing means according to any of the preceding claims in which the mixing means includes amplifying means for amplifying the input signal prior to feeding the latter to the input signal.

7. Input circuitry for mixing means according to any of the preceding claims, the input circuitry comprising a signal

splitter for separating alternate half wave cycles of an oscillating input signal, inverter means for inverting one set of half wave cycles and that said half wave cycles constitute two unidirectional pulse trains which, in combination, represent the input signal in amplitude and phase.

8. Input circuitry according to claim 7 in which the signal splitter and inverting means comprise an interconnected cascade of transistors which also amplifies said half wave cycles.

9. Mixing means substantially as described herein with reference to and as illustrated in, Figure 1 of the accompanying drawings.

10. Mixing means substantially as described herein with reference to, and as illustrated in, Figure 7 of the accompanying drawings.

11. Input circuitry substantially as described herein with reference to, and as illustrated in, any of Figures 1, 2 and 4 to 6 of the accompanying drawings.

The Patent Office

Application No:	GB 9514944.9	**Examiner:**	Mr.S.SATKURUNATH
Claims searched:	ALL	**Date of search:**	28 September 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): H3R:RMB, RMC, RMX

Int Cl (Ed.6): H03B, H03C

Other: Online: WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		